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METEORITES LARGE AND SMALL*

BY JOHN F. HEARD

Introduction

Others thought that a stone which, according to the common opinion, fell from heaven, was an omen of the overthrow. It fell at Aegos Potamos, and was of a prodigious size. The people of the Chersonesus hold it in great veneration, and show it to this day. . . . After this body was fallen in the Chersonesus, and the inhabitants, recovered from their terror, assembled to see it, they could find no inflammable matter, or the least sign of fire, but a real stone, which though large, was nothing to the size of that fiery globe they had seen in the sky, but appeared only as a bit crumbled from it.

These sentences are from Plutarch's *Life of Lysander,* written about 100 A.D., referring to an event which was supposed to have taken place about 500 years earlier during the war between the Athenians and the Peloponnesians. It is not difficult to believe now that the reference is to a real natural phenomenon—a great blaze of light across the sky, which must have lit up the whole of the Near East, a shock wave which reverberated through the hills and a plunging to the earth of a great black stone which some, as Plutarch tells us, thought was wrested from a hill-top by a tempest while others thought it truly fell from heaven.

It is not, as I say, difficult for us to believe this version nowadays because the falls of great meteorites have been witnessed many times, but as late as 150 years ago scientists and other educated people were only beginning to believe that the legends of "stones from heaven" had any basis of truth. In 1807 President Thomas Jefferson was reputed to have said of a reported fall of a stone from the sky, "I could more easily believe that two Yankee professors would lie than that stones would fall

*Presidential Address delivered at the Annual Meeting of the Royal Astronomical Society of Canada, January 14, 1955.

from heaven." Perhaps the woman in Alabama who was hit by a falling meteorite last December had more reason to be convinced. (This, I believe, is the first recorded human casualty from a falling meteorite, although Watson (1941) has estimated that five or six meteorites, totalling about half a ton of material, fall on the earth each day).

Meteorites have been recovered by the thousands. If anyone hasn't seen one it is because he hasn't looked for them in museums. If anyone doesn't own a small one it may be because he doesn't know that he can buy one from a science supply company for a few dollars. In Canada we have fine collections at the Royal Ontario Museum in Toronto and with the Geological Survey in Ottawa. A 386 pound specimen, the largest meteorite recovered in Canada, is on display at Victoria College in Toronto, and a 90 pound stone which fell at Dresden, Ont., is on display at the University of Western Ontario in London. Millman (1953) has recently published a catalogue of Canadian meteorites; he has recorded 6 separate witnessed "falls" and 18 separate identified "finds". The latest in his list is the witnessed fall of a 237 pound stone at Abee, Alberta, in June 1952. This specimen is now in the collection of the Geological Survey in Ottawa.

Meteorite Searches

The fact that only 24 separate "finds" and "falls" are recorded for Canada, while in the United States there are nearly a thousand, is largely because our country is relatively sparsely populated, but also it is partly because we have not conducted meteorite hunts as systematically as have some American astronomers. In particular Dr. and Mrs. H. H. Nininger (1950) since 1924 have been conducting an extensive campaign of searching for meteorites in the United States. Their policy has been to favour areas of light rainfall not too much infested by rocks, where the population is relatively dense and where cultivation is practised; all these things favour the preservation and discovery of meteorites. By a programme of lectures in schools in such areas they disseminate knowledge of the recognition of meteorites and of their scientific importance. In this way they have often brought to light, for example, the memory of a farmer once bending a plowshare on an unusually heavy rock. In addition they search areas corresponding to the "ground points" of fireballs which they have worked out from analyses of observations. They offer to buy meteorites at a rate of about a dollar a pound and, to cover the cost of their operations, they resell specimens at a moderate profit. In this way they are now accounting for about half the meteorite discoveries of the world. I wonder if this is not the kind of programme which

could be organized among members of our Society. Dr. P. M. Millman, well known to readers of the JOURNAL, has investigated a number of witnessed falls and reported finds. From my own limited experience in investigating fireballs, I know that about one person in four in country districts "knows someone who has a meteorite"; I think that most of these "meteorites" are just curious stones, but I have begun to wonder if we should not investigate more of these rumours by some organized division of labour.

At this point I should say how to recognize a meteorite. But perhaps I should remind you first that meteorites fall into three groups, those composed almost entirely of iron and nickel, those composed of stone, and, more rarely, those which are a conspicuous mixture of iron and stone. The irons are easily identified because of their weight—hardly anyone would fail to be impressed by finding a rounded lump of iron even if it were covered by a black crust as the iron meteorites often are. On the other hand, the identification of a stone meteorite is usually the job for an expert, but one might be suspicious of any stone found under unusual circumstances, for example, on top of the snow or ice, or turned up by a plow in a field which in previous cultivations never yielded any stones. If the stone is smooth and covered with a dark crust it is particularly worthy of investigation—if it is jagged and gaily coloured it is almost certainly not a meteorite.

The Largest Meteorites

The largest meteorite known is the Hoba West iron meteorite, believed to weigh about 60 tons, which lies where it fell in South-West Africa. It is relatively safe from souvenir hunters, for it took two natives two days and a great many hack-saw blades to cut a few cubic inches from it. The second largest, the Ahnighito, also an iron, weighing 33 tons, has been seen by those who have visited the Hayden Planetarium in New York; it is one of three brought to the United States from Greenland by Commodore Perry in 1897. The third, also an iron, known as Bacubirito, of estimated weight 24 tons, is in Mexico. The fourth, an iron again, also at the Hayden Planetarium, the Willamette (Oregon) weighs 14 tons. By comparison the largest meteorite found in Canada is the 386 pound iron found in 1869 at Iron Creek, Alberta—the one now exhibited at Victoria College, Toronto. The largest stone meteorites tend to be smaller than the largest irons. Perhaps this is because the stones have been more susceptible to fracture. Certainly we know that many stones have broken in the atmosphere. The two masses which comprised the Shelburne, Ont., fall of August 1904 were found a half a mile apart.

They fit together and their fitting surfaces are encrusted by melting, but not so heavily as the other surfaces. It is as though the original broke in the course of that part of its flight which caused the surface melting.

Origin of Meteorites

I have implied in the foregoing remarks the fact known to everyone, that the meteorites are the remains of fragments of interplanetary matter intercepted by the earth. They suffer surface melting from the heat developed as they dash through the earth's atmosphere between the 60-mile and the 10-mile level, and sometimes they are fractured by this heating. The heating produces the blaze of light which we call a meteor, or, if very bright, a fireball. Not every fragment of interplanetary material survives the heating to reach the earth as a discrete particle; the smaller ones, accounting for "shooting stars," are believed to be completely vaporized. Those big enough to survive in part are so slowed in the lower layers of the atmosphere that they have already cooled by the time they reach the earth. Concentrating our attention now on the fragments which do survive, we may well ask what we know of their origin. Are they from within the solar system or from without? If from within, are they from comets, from asteroids, or are they just stray lumps of matter hitting the earth by chance? The answer, given with increasing conviction, is that these larger fragments which have survived as meteorites came from among the asteroids. Two lines of argument bear this out, namely the information on their orbits and the information on their constitution and structure. Let us, however, first be reminded concerning the asteroids.

Between the orbits of Mars and Jupiter there exist planets by the thousands, called asteroids, all very small, only a few of them exceeding a hundred miles in diameter and ranging down to a mile or so in diameter, the smallest which one could expect to see with existing telescopes. No doubt still smaller ones exist by the millions, for the asteroids must suffer many fracturing collisions among themselves. The total mass of the asteroids has been estimated by Kuiper (1953) to be less than a thousandth part of the earth's mass.

Now, when a bright fireball accompanying the fall of a meteorite has been well observed, it has often been possible to calculate the orbit of the fragment as it entered the earth's atmosphere. It has turned out that such orbits resemble the orbits of the asteroids. This resemblance alone is perhaps sufficient to identify the meteorites with the asteroids. The matter of the constitution and structure of the meteorites makes the identity still more plausible and, at the same time, if we are prepared to

accept the identity, it may shed light on the nature and origin of the asteroids themselves.

We have seen that the meteorites are some almost wholly iron and nickel, some stoney and some mixtures of iron and stone. Now we have good reason to believe that the earth has a core of nickel-iron and a mantle of stoney material. It is supposed that the separation took place through a gravitational movement of the heavier iron to the centre. It is tempting to believe that the separation of meteorite material into stone and iron also took place in a body or bodies large enough to effect the separation gravitationally and that this body or bodies later suffered fracture. In fact, it is difficult to envisage any other process which could account for bodies of pure metal and bodies of stone. However, the separation of light and heavy materials in stone meteorites appears to be not as complete as in the rocks of the earth, and a study of this difference has led Kuiper (1953) to conclude that the meteorites were formed in bodies whose surface gravities were extremely small relative to that of the earth. From this and other considerations Kuiper has come to the conclusion that the present asteroid belt is occupied by the accumulated fragments of collisions of a few larger asteroids, say five to ten of them, each a few hundred miles in diameter, which suffered repeated and increasingly frequent collisions and pulverization. The meteorites are fragments which have been "thrown off the track" and have been swept up by the earth in its motion about the sun.

Close study of the iron meteorites has supported the view that this material was formed in the interior of one or more larger bodies. An iron meteorite, if cross-sectioned, polished and etched with acid, reveals curious criss-cross markings called Widmanstätten figures. These figures have been studied in detail for hardness by F. K. Dalton (1950, 1951), a recent winner of the Society's Chant Medal. They are believed by mineralogists to be evidence of the slow cooling of large crystals which existed during the early stages of solidification of the metal. The extremely slow cooling is an indication that the material cooled while insulated deep within a larger body. Geophysicists believe that the earth's core is only now solidifying; the cores of asteroids solidified earlier, supposedly because of their smaller size.

The foregoing remarks apply to the bodies which cause fireballs or extremely bright meteors and which drop meteorites. In the same class as regards origin we may place those still bigger and rarer bodies which cause meteor craters. The principal difference may be that the larger bodies carry so much momentum that they literally explode on hitting the ground. Meteor Crater in Arizona, according to Öpik (1950), may

have been caused by an asteroid 100 yards in diameter crashing to earth with a velocity of 5 to 10 miles per second. Whether or not a main mass survives below the crater remains uncertain, but many small fragments of meteoritic iron have been found over a wide area surrounding the crater. In the case of the Ungava Crater, Meen's (1950) search has revealed no meteoritic material; it may be that the colliding body was completely vaporized.

Before leaving the subject of meteorites, large, let me repeat that Watson's estimate of the average daily fall of these bodies is about half a ton.

The Material from Meteors

By meteors we mean the relatively unspectacular phenomena of the shooting stars which may be seen any hour of a clear night (sporadic meteors) and in particular abundance at the time of meteor showers. The shower meteors are known to be closely associated with comets and are believed to be caused by cometary fragments passing into the earth's atmosphere. The similarity between sporadic and shower meteors has led many investigators to believe that the sporadic meteors are also caused by cometary fragments which have become dispersed in the course of time and no longer display association with particular comets. If we may accept this idea we may consider both these types of meteors together.

Do the meteors drop meteorites as do the fireballs? Apparently not, for there is no known instance of a meteorite falling at the time of a meteor shower. Apparently the bodies responsible for meteors are small enough to be vaporized before reaching the earth. Indeed Whipple (1952a) has suggested that the particles responsible for meteors are porous, fragile structures as contrasted with the dense, solid meteorites.

Watson (1941) has studied, by theoretical calculations, the relationship between brightness of meteors and the masses of the particles causing them. He has concluded that they range from a few ounces for the brightest down to about a milligram for the faintest visible to the naked eye. He has also estimated the total number of meteors in the various brightness classes and has totalled the mass of all meteors, including those too faint to be seen by the naked eye. His answer is about a ton a day, that is, about twice the total mass of the meteorites. This material, though perhaps not surviving in the form of discrete particles, must nevertheless be considered as contributing to the earth's accumulation of meteoritic matter. We have seen that it comes from comets. Comets are vastly different from asteroids. According to recent views of Whipple and of Kuiper, they are composed largely of snow and ices with imbedded

particles of minerals and they were formed in the remote regions of the solar system beyond the orbit of Pluto.

Micrometeorites

Over the past hundred years many efforts have been made to recognize small meteoritic particles in the dust falling to earth or washed down by rain. I shall have more to say of these efforts shortly, but first I would like to call attention to two important lines of investigation of a less direct nature, one showing how particles which are small enough can pass intact through the atmosphere without vaporizing, the other showing that there is an abundant supply of these small particles in the space through which the earth moves.

The first line of investigation is that which has been pursued by Whipple (1950, 1951a) following ideas put forward earlier by Öpik (1937, 1951). The reasoning is somewhat as follows. It is the collisions with air molecules which slow down a meteoritic particle and which transform its energy of motion into heat. The heat so gained will be in part re-radiated, and the remainder will serve to raise the temperature of the particle. The question is, will the rise in temperature be sufficiently rapid for the particle to reach the melting point before its velocity is appreciably reduced? For larger bodies the answer is certainly yes, as we know from observation of ordinary meteors and meteorites. But we could expect it to be otherwise for smaller particles because, as we consider smaller and smaller particles, the surface area of the particles (on which the re-radiation depends) decreases less rapidly than does the mass (on which the energy of collision depends). That is, we could expect to reach a size small enough so that the re-radiation of the energy of collision is great enough to keep the temperature too low for vaporization and, in fact, even for melting. Whipple has calculated that the largest spherical particles which will not be melted range from about 4 microns* in diameter for particles entering the atmosphere at 25 km./sec. up to about 25 microns for particles entering at 11 km./sec. Still larger particles would become hot enough to melt but not to vaporize.

The other line of investigation to which I have referred, having to do with a possible source of micrometeorites, is that of van de Hulst (1947) which has shown that the observed light of the outer corona of the sun and of the zodiacal light can be explained as scattered sunlight from a quiescent haze of small dust particles in the plane of the ecliptic in interplanetary space. Almost all of these particles are smaller in diameter than 700 microns and increase in number with decreasing size. Assuming

*A micron, abbreviated μ, is 0.001 mm. or about $\frac{1}{25000}$ in.

that telescopic meteors originate from particles ranging in diameter from 200 to 600 microns, van de Hulst has concluded that the number of his predicted dust particles in this size range is about 10,000 times larger than can be inferred from the number of observed telescopic meteors. The only way to explain this is to assume that only a small fraction of these particles enter the earth with velocities sufficiently high to cause visible meteors. Van de Hulst has estimated that the amount of this material swept up by the earth should total at least 1000 tons per day. This is about 1000 times the amount predicted from observation of all visual meteors including fireballs which drop large meteorites.

Collecting Meteoritic Dust

We now enquire as to what confirmation we can find, if any, for the surprisingly large predicted figure for the amount of meteoritic dust. Can we, for example, collect and identify micrometeorites which drift down to earth? Many investigations of this kind have been made, and these have been summarized recently by Buddhue (1950).

The immediate difficulty that all investigations in this field anticipate and encounter is how to distinguish meteoritic dust particles from terrestrial dust particles which, we know for certain, are blown out from volcanoes, spewed out of smoke stacks and carried aloft from the surface by wind. It would no doubt be helpful to make collections far from volcanoes and from cities and in the snow-covered Arctic, but nowhere can we expect to be quite free from terrestrial dust, for such dust may be carried thousands of miles by winds. Spherical particles of diameter 20 microns and density 3 gm./c.c. fall through the atmosphere at a rate of only about 250 feet per hour. It would not therefore take a very great updraft to carry them aloft. We know that dust from the explosion of Krakatoa in 1883, from the Siberian meteorite fall in 1908, and from the Alberta "blue sun" Muskeg fire smoke in September 1950, stayed aloft long enough to be transported thousands of miles.

All meteoritic dust collectors have recognized the fact that any collections will be strongly contaminated by terrestrial dust, and so they have made efforts to sort the supposedly meteoritic from the terrestrial. Almost all have assumed that magnetic particles, consisting of iron or iron compounds are probably of meteoritic origin. Some have made collections of all dust falling on glycerine coated plates and have then sorted out the magnetic material with a magnet; others have collected with a magnet the magnetic particles which are washed down the down-pipe from a roof. All these collectors have found that a considerable proportion of the magnetic dust particles consists of shiny dark spheres in the size range

5 to 30 microns diameter. Collections of these little spheres have been analysed and found to consist largely of magnetite, an iron oxide which is common in the black crust of meteorites. To bolster the suggestion that these magnetite spheres are indeed meteoritic, efforts have been made to show that they contain nickel in a higher proportion than does terrestrial magnetite. The evidence in this regard I find rather inconclusive. Nevertheless, I think we can say that the belief has commonly been held that the black spheres are of meteoritic origin. However, for reasons which I will come to shortly, I think there is now reason for grave doubt on this score.

It is easy enough to collect a few of these black spheres. All you need is a strong magnet with a piece of cellophane held over the poles. Pat the magnet on a rooftop and in a few minutes you will have picked up some of the spheres. If your eyes are good you can see them well enough to slide them off the cellophane onto the stage of a microscope. Mr. Allan Smith of Markham, Ont., a member of our Society, has collected and photographed hundreds of these spheres.

Buddhue (1950) does not suppose that all micrometorites fall in the form of the black spheres. He believes these latter to be droplets atomized from the melting of the surface of larger meteorites. Supposedly other small particles fall without melting and are not readily identified in the collections.

Several investigators have made estimates of the amount of material falling on the earth in the form of the black spheres. Buddhue (1950) has expressed his results in terms of mean annual rainfall over the earth. His result is about 2000 tons per inch of rainfall. Thus if the mean annual rainfall is 30 inches, the annual fall of spheres amounts to about 60,000 tons; Thomsen (1952) gets a much higher value, about 2,000,000 tons.

Buddhue (1950) has found seasonal variations in the number of spheres he has collected and has correlated these variations with the meteor showers, finding that the largest number of spheres are collected a few days after meteor showers. However, he has experienced some difficulty in making the apparent correlation consistent with computed times of fall of the particles. Yet, other investigators quoted by Buddhue have noted similar correlations, and in this same connection I might mention here that Bowen (1953) in Australia has recently interpreted some rainfall data in terms of meteor showers. He has found that over the years at a number of places for which rainfall data are available there are dates of rainfall peaks which follow the principal meteor showers by about 30 days. He calculates that particles of diameter 1 to 4 microns fall from the 100 km. level to cloud-top level in about 30 to 50 days. He

interprets the rainfall peaks as being caused by the seeding of the clouds by these small particles. Millman (1954) has objected to Bowen's interpretation on several apparently valid grounds. If these objections can be met, it may be that rainfall data may shed some new light on the fall of meteoritic dust.

Possible Terrestrial Origin of Black Spheres

To return to the question of the black magnetic spheres, there are several recent investigations that throw serious doubt on their origin being anything but terrestrial. During 1947 and 1948 the late Dr. F. S. Hogg and D. K. Norris (1949) of the David Dunlap Observatory made collections of falling dust in localities ranging from Richmond Hill, Ont. to Baker Lake, N.W.T. They examinned the magnetic content of these dust collections and concluded that spherical particles were more frequent in collections made near sources of industrial smoke than in regions remote from industry, while a few bright, metallic, splinter-shaped particles occurred with about the same concentration in all localities. It was to these bright splinters that they attributed meteoritic origin, especially in view of a positive test for the presence of nickel in one of them.

A year ago we had an opportunity to extend this kind of investigation when there became available to us some collections of dust made by a filtering device operated in an aircraft during flights of several hours at an altitude of 6000 feet in the Arctic. These collections each represented the filtering of about 300,000 cu. ft. of air. Mr. John Martin, a student assistant at the Observatory, and I have studied these collections in an effort to discover what we could of their meteoritic content.

These collections came to us in two forms: for one collection we had the filter itself with the particles imbedded in it, for the other we had a residue of the solid particles in a bit of water, the result of the filter having been dissolved chemically and the precipitate recovered from the solution by washing and centrifuging.

In the course of sampling this Arctic material both in the precipitated form and on the filter itself, a total of 1950 particles were examined under a microscope of 100-power carefully enough to form estimates of their size. We identified only two of these as black spheres. For comparison purposes we made similar counts and size estimates on a sample of dust collected from the air in a similar manner at Windsor, Ont., a place where there is much industrial pollution of the atmosphere. Out of 2350 of these Windsor particles we identified 36 of the shiny black spheres similar to these which can be picked up from roof-tops. This lends numerical support to the impression formed by Hogg and Norris that

the spheres are more frequent in industrial areas, especially when we realize that, if the spheres were meteoritic, they should be proportionally more abundant in the less polluted air. On the other hand, we did not observe any of the bright metallic splinters which Hogg and Norris collected and which they believed to be meteoritic.

The figures quoted above suggest strongly that the black spheres are not meteoritic but are the products of industry. Other strong support for this view is found in a paper by Handy and Davidson (1953) who have examined the magnetic fraction of fly ash collected from chimneys of industrial plants. They have found this magnetic fraction to be mostly shiny, black spheres strikingly similar, in appearance and size, to the supposed meteoritic spheres. They have gone further: estimating the amount of fly ash released to the atmosphere in the United States, they have found that this could just account for the fall of supposed meteoritic material calculated by one investigator on the basis of his collections of magnetic spheres in Iowa.

Although we concluded that black spheres are probably not meteoritic we did not dismiss summarily the rest of the Arctic dust collection. One thing which we did was to estimate the total weight of the collected material. For the precipitated sample this was done by estimating the volume, allowing for the packing factor and assuming a mean density of 3 gm./c.c. For the sample still on the filter, counts and estimates of mean diameters of particles were made under a microscope, over a number of sample areas and a calculation of total mass was made, again assuming a mean density of 3 gm./c.c. for the particles. In both cases the total mass came to approximately 20 milligrams. Thus we may say that the Arctic air at 6000 feet contained about 7×10^{-8} grams of solid material per cubic foot at the time of the collections.

From our counts we had the numbers of particles in the various size groups which were suspended in 300,000 cubic feet of air. We then calculated the terminal velocities of these various sized particles from Stokes' law and so computed the total mass of material which must be falling to earth. This amounted to several million tons per day for the whole earth, thus exceeding van de Hulst's forecast by a factor of 1000. Perhaps we should simply conclude that only one particle in 1000 of our collection is meteoritic. However, we estimated that only a few per cent. of our particles are magnetic. If we may assume that all meteoritic material is magnetic, then we may conclude that the magnetic fraction of our collection represents from 10 to 100 times the amount expected from van de Hulst's calculations. In any event it is difficult to escape the conclusion that much the greater part of the collection is terrestrial in origin.

Other Methods of Detecting Micrometeorites

If the lower levels of the air are too much contaminated by terrestrial dust, one naturally thinks of the possibility of detecting them in rocket flights which have been made to heights of more than a hundred miles. An experiment was, in fact, made by Bohn and Nadig (1950) which seems to indicate detection of particles at these heights. They studied high frequency sound "pings" on the nose cones of V-2 rockets. They recorded about 60 such pings in a flight of about two minutes, and they estimated that the particles responsible might have had diameters of about 2 microns and that they were present in a concentration of about one particle per four thousand cubic feet. Whipple (1952b) who has quoted this result, has also referred to observations by Burnight of the pitting of polished surfaces of rockets which may be ascribable to particles of somewhat larger size in a concentration of about two particles per thousand cubic feet. In support of these figures Whipple also refers to collections of particles made during flights in aircraft at high altitude in clean northern air by Crozier and Seely (1950) which amount to one particle larger than 10 microns to every 4 cubic feet. (In our collections we count two particles larger than 12 microns to each cubic foot).

An observation of a different sort which may have to do with the earth's accumulation of meteoritic material is that of Pettersson and Rotschi of Sweden (1950). They have made quantitative tests for nickel in cores of deep sea sediments taken from both the Atlantic and the Pacific oceans. For one thing the nickel content was unexpectedly high in both. For another thing the core from the Pacific gave about ten times the nickel content of the one from the Atlantic, whereas the relative radium content of the two cores indicated that the Atlantic sediment was being deposited about ten times as rapidly. An interpretation of this observation therefore requires a source of nickel independent of the rate of sedimentation. Pettersson and Rotschi have discussed several possible sources, and they consider the fall of meteoritic material as the most likely explanation. Their results would be satisfied by the fall of several thousand tons per day of material containing 2 per cent. of nickel by weight. Whipple (1952b), discussing this result, has noted that it is in excellent agreement with van de Hulst's calculation and he has computed that if this were all concentrated in 10-micron particles we should expect to find one particle per 400 cubic feet in the atmosphere.

The observations just referred to are not the first which have suggested that meteoritic material is to be found in the ocean sediments. More than seventy years ago Murray and Renard (1884) took samples of red clay from the ocean bottom during the H. M. S. *Challenger*

expedition. They found in this clay a small number of magnetic black spheres of diameters up to one-fifth of a millimetre (200 microns) which appeared to have shells of magnetite and cores of iron and which they believed were meteoritic. A quart of the clay would contain only a few of these spheres. Since the clay was laid down at a rate of only a fraction of a millimetre per year, the total deposit of material in this form need not be great. Buddhue (1950) has estimated that it could be accounted for by an annual fall over the whole earth of only about 8 tons; he believes that these "deep sea spherules" form only a small part of the annual accretion of meteoritic material. The "deep sea spherules" cannot be identified exactly with the black spheres picked up in dust collections and from rain water; the former are larger and have characteristic markings not found on the others.

Summary of Micrometeorites

This has been far from a complete survey of the great mass of literature on the subject of meteoritic dust, yet I think it may have served to illustrate the various attacks on the problem. Let me summarize the ideas and information to which I have referred.

Van de Hulst has shown by an indirect but convincing method that the earth's daily accumulation of dust from interplanetary space must amount to several thousand tons a day. Measured nickel content of ocean floor sediments, if it is to be explained by the fall of meteoritic material containing 2 per cent. nickel, also requires a daily accumulation of several thousand tons a day. The deep sea spherules consisting largely of iron could be accounted for by a rate of a few hundred pounds a day. Experiments with V-2 rockets in the upper atmosphere have indicated impacts of small particles with a frequency not inconsistent with the figure of a thousand tons a day. Collections of airborne dust at 6000 feet in the Arctic, however, would give a rate of accumulation of millions of tons a day, but probably only a small fraction of this material is extraterrestrial in origin. Meteoritic origin has been attributed to small magnetic black spheres collected by a number of investigators, but collections in the Arctic contain fewer of these in proportion than do collections made near industrial areas and this fact casts doubt on their meteorite origin; furthermore magnetic spheres extracted from fly ash bear a striking resemblance to these supposed micrometeorites.

The Origin of Micrometeorites

Suppose we accept the evidence from the zodiacal light and from the nickel content of the ocean bed that one to ten thousand tons of interplanetary dust of some form or other comes to the earth each day. The

next question which comes to mind is, what is the ultimate source of the dust?

Whipple (1951b) has concluded that the zodiacal dust cloud may be sustained by the addition of fragments lost from comets, but Öpik (1951), on the evidence of the quiescent nature of the cloud relative to the earth, believes that it arises from some other source.

He has seen in the size distribution of the particles a means of testing between two alternatives, (a) that the dust has come into being relatively recently through collisions among the asteroids and (b) that the dust is primordial, that is, left-over material from the dust cloud out of which the solar system was formed. If the particles come from beyond Jupiter and Saturn the route by which they reach the earth is a slow inward spiralling under an impeding action of sunlight known as the Poynting-Robertson effect. This would cause smaller particles to spiral more rapidly than larger ones. The larger ones, therefore, would linger longer on orbits near Jupiter and Saturn and would, accordingly, be swept up in large measure by these planets. This is consistent with van de Hulst's (1947) findings, namely that the number of particles involved in the zodiacal light drops off abruptly at diameter 700 microns. If, on the other hand, the particles originated in the asteroid belt, there would be no explanation for the observed size distribution, for the filtering action of Mars would not be great. Thus, Öpik's conclusion is that the dust particles concerned in the zodiacal light and the deep-sea nickel are mainly primordial rather than fragments of asteroids.

Conclusion

We have seen that the meteoritic material which is known or believed to be falling to the earth may be divided into three quite distinct classes as to evidence and origin.

First there are the meteorites which are dropped from fireballs. The evidence for these could not be more direct. The amount is about half a ton a day on the average. There are excellent reasons to believe that these are bodies escaped from the asteroid belt and that they represent fragments from collisions among a few small planets which were formed along with the other planets in the region between the orbits of Mars and Jupiter.

Secondly, there is material inferred to come from meteors. We have no samples of this material identified with certainty since the particles are probably vaporized in passing through the atmosphere. However, from the number of meteors and their brightness it has been possible to estimate the amount of material added to the earth in this way; it

amounts to several tons per day. The material of meteors is believed to originate from the comets which, in turn, were formed from the primordial material of the solar system in its outermost regions.

Thirdly, in the neighbourhood of the earth there is known to exist material in such finely divided form that it must pass through the earth's atmosphere without causing meteors at all and reach the surface as dust particles. Indications are that the earth must sweep up daily about a thousand tons of this material. Although the evidence from attempts to collect falling micrometeorites is not altogether conclusive, there is confirming evidence of the estimated amount in the high nickel content of the ocean sediments. This interplanetary dust is believed to be primordial rather than to have stemmed from larger bodies.

If these presently-favoured views are correct we have then, descending upon the earth, fragments of planets and of comets and, as well, samples of the material from which these bodies were originally formed. Further study of meteorites and micrometeorites can hardly fail, therefore, to add to our knowledge of the origin and history of the solar system.

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ROBERT MELDRUM STEWART

DECEMBER 15, 1878—SEPTEMBER 2, 1954

By MIRIAM S. BURLAND

CANADA'S scientific fraternity lost a loyal and faithful colleague when Robert Meldrum Stewart died on September 2, 1954. His death came as a great shock to his many friends, for until quite recently Mr. Stewart had taken a keen interest in his chosen field of astronomy, and was not an unfamiliar visitor at the Dominion Observatory whose destiny he had guided for many years.

Born of Scottish-Canadian parents in Gladstone, Manitoba on December 15, 1878, he was the son of the Rev. James J. and Mrs. Stewart. As a Presbyterian minister, Rev. Stewart was engaged in missionary work in Manitoba at the time of his son's birth, but later the family moved to Ontario and resided in various communities. It is perhaps because of this frequent moving that young Meldrum did not attend school until the age of eleven. However under the expert tutoring of his father, who had been a teacher prior to entering the ministry, the young lad was coached in Greek, Hebrew and Latin in addition to the subjects necessary for his entrance examinations. With this background the future Dominion Astronomer obtained his entrance certificate at the age of ten and entered High School at eleven. At Jarvis Collegiate, Toronto he continued his studies and later attended Lisgar Collegiate, Ottawa. It was from the latter institution that Meldrum Stewart proceeded to the University of Toronto, having won practically all the available scholarships.

At the University he followed the course in Mathematics and Physics graduating with high honours and winning the much coveted Gold Medal in 1902. The following year he was granted his master's degree. Because of his cultural background and love of the classics, he managed to continue his study of English Literature while pursuing his scientific work, thus giving him a well balanced education and a love for and appreciation of the finer things of life.

Like many other Canadians who have entered the field of astronomy as a life work, Mr. Stewart came under the guiding influence and supervision of Dr. C. A. Chant who is still active at the David Dunlap Observatory. Mr. Stewart's astronomical interests, however, go farther back than his college days, and his wife tells of how he liked to recall that as a small boy his father would take him walking at night and would explain the movements of the stars and planets.

R. Meldrum Stewart, 1878–1954.

At the turn of the century, the Astronomical Branch of the Department of the Interior was in its infancy but eager to engage promising young scientists. It was not surprising that Mr. Stewart, considered one of the top mathematicians of his day, should have joined that branch in 1902 and may truly be called one of the pioneers of Canadian astronomy. At that time the staff was few in number and occupied rooms near the Parliament Buildings, while the observing was done in a small frame building on the bank of the Ottawa River near the end of Cliff Street.

In those early days the work of the branch dealt chiefly with accurate latitude and longitude determinations. In the development and expansion of a young country it was of prime importance to have accurately known positions for a network of points, and this work had been initiated in connection with the construction of the transcontinental railways.

From the time of his first association with the branch, Mr. Stewart took a most active part in the latitude and longitude work. Fired with

the eagerness of youth and with a desire to increase the efficiency of the results, he started a modest time service in 1903. In 1904 an appropriation of $5000.00 was made by Parliament for the installation of electric clocks in Government buildings, to be controlled and serviced by the new Observatory. When the staff moved to the present building in the spring of 1905, Mr. Stewart was made Superintendent of the Time Service, and remained head of that division until he was named Director of the Dominion Observatory in 1924. Upon his shoulders fell the work of establishing this important phase of astronomy, and to him must go much of the credit for developing Canada's Time Service to the high degree of efficiency which it has attained.

Since it was in the development of Positional Astronomy and the Canadian Time Service that Mr. Stewart made his greatest contribution to science, a few landmarks in that development and its associated work should be mentioned. It is natural that during the first few years in the new building much time was required for organization and for making sound plans upon which the future of the Observatory would be founded. When the present 6-inch Meridian Circle telescope was obtained in 1907, it was Mr. Stewart's responsibility to supervise its installation. The usual number of problems were encountered, but with their solution a regular programme of observations was commenced. For many years Mr. Stewart not only supervised this work personally, but also took a major share in the observations. The first extensive observing programme for the accurate positions of stars was completed in 1923 and three catalogues of many thousands of stars have now been observed and the results published. Observations with this instrument also formed the basis for the determination of accurate time until 1935.

When the longitude programme was extended to stations where telegraphic communications were not available, it was Mr. Stewart who devised the system of determining longitude by the use of wireless time signals. The first station thus occupied was at Quinze Dam, Quebec in 1914. In 1923 the Observatory discontinued longitude work in connection with surveying, but retained its active interest in the scientific aspects of the problem. Under Mr. Stewart's direction Canada participated in two world longitude programmes. In 1926 the network comprised 40 stations encircling the globe and representing 20 countries. A similar programme was undertaken in 1933 with the Dominion Observatory again taking an active part.

Meanwhile there was an increasing need for the distribution of time to many parts of the country and it was foreseen that the meagre system of wireless time signals then in use would need vast improvement and

extension in the years ahead. Time impulses had been sent from the Observatory to the local telegraph offices as early as 1905, but the first wireless transmission over local broadcasting stations did not come until 1923. Four years later radio broadcasting was to emanate directly from the Observatory, using short wave frequency.

About this time an idea was evolving in the fertile mind of Mr. Stewart and his conception was later to be realized with the construction, in the machine shop of the Observatory, of his Time Signal machine. In 1938 this machine went into operation. A pendulum provided the control for the instrument, which at that time was cleverly held to true time by a Shortt pendulum clock. When a crystal clock was installed in 1942 it became the controlling unit rather than the Shortt clock. Services supplied by this machine included (1) The noon broadcast over the C.B.C. network; (2) Continuous short wave signals from C.H.U. on three frequencies; (3) Other radio transmissions such as C.N. and C.P. Telegraph companies; (4) Additional services including the control of 800 dials in 14 Government buildings.

Mr. Stewart's general interest in science was very broad, his particular interests ranged from radio-activity, meridian work, time service, longitude by wireless to the theory of errors. During his 44 years of active association with the Observatory, he did much to shape the policy of that institution and to lay the foundation for the position it holds in both astronomical and geophysical fields. As Dominion Astronomer his administrative duties increased with the passing of years, but in spite of this his constructive interest in all research problems of the Observatory never waned. As a lecturer and writer he was well known, and many of his scientific articles have appeared in this JOURNAL.

Meldrum Stewart was not one given to joining many organizations other than those of a scientific nature. During his professional career, he held office or took an active interest in the following: Chairman, National Committee for Canada, International Astronomical Union; Chairman, Section D, American Association for the Advancement of Science; Fellow of the Royal Astronomical Society; Fellow of the Royal Society of Canada; Fellow of the Royal Astronomical Society of Canada, and President in 1924, Honorary President in 1931 and at one time President of the Ottawa Centre and member of its Council for many years; Member of the American Astronomical Society, the Astronomische Gesellschaft and of La Société Astronomique de France.

Had Mr. Stewart lived a few months longer he would have seen the realization of one of his dreams—the construction of an annex to the Observatory. Several times during his tenure of office, plans were laid

for an extension to the Observatory to accommodate the additional staff and to provide much needed laboratory facilities, but periods of retrenchment and war made it necessary to postpone any building expansion. A well equipped building, in the planning of which Mr. Stewart had a part, will be ready for occupation early in 1955; this annex to the Observatory will provide office space, laboratories and an assembly hall.

In his younger days Mr. Stewart was interested in boxing, boating and tennis and as a member of the Westboro Lawn Bowling and Tennis Club, he continued his activity in tennis for some years. Boating, however, was his chief outdoor recreation in later years and it was a familiar sight to see him working on his yacht at the Rideau Aquatic Club. He retained his membership in that club for some years and at one time was elected Rear Commodore. His indoor interests included carpentry and chess, and like many other scientists, a fondness for music. Following in the tradition of his father, Mr. Stewart and his family were members of St. Andrews Presbyterian Church, Ottawa.

Because of his retiring nature, it was not given to many to know Mr. Stewart intimately, but he will be remembered by all for his keen sense of integrity. Those who, like the writer, were privileged to be associated with him in his scientific work knew him as a brilliant mathematician and learned to appreciate his many sterling qualities.

Astronomy has suffered a severe blow. Let us never forget the debt of gratitude we owe to the scientific pioneers of our country. Without men like Robert Meldrum Stewart, Canadian astronomical and geophysical research would not have attained the position they now hold in scientific circles.

Mr. Stewart is survived by his widow, the former May Dickson, whom he married in 1904, two daughters, Mrs. W. K. Ross of Montreal and Mrs. Wilfrid Saunders of Toronto and six grandchildren. Two other daughters, Dorothy and Molly, predeceased him, and also a son who died in infancy. The sympathy of all is extended to the bereaved family.

Dominion Observatory,
Ottawa,
December 1954.

SOLAR ECLIPSES OF LONG DURATION OF TOTALITY

By Charles H. Smiley and Mary Quirk

According to the *American Ephemeris and Nautical Almanac* for 1955, the total solar eclipse of June 20, 1955 will have a duration of totality of 7 minutes 8 seconds at a point 14°45′N., 116°57′E. This is some 4 seconds longer than the greatest duration of totality for the solar eclipse of June 8, 1937 (at 9°54′N., 130°40′ W.) and a second or so longer than that for the eclipse of June 30, 1973 (at 18°44′ N., 6°07′ E.). Two questions naturally arise: How long has it been since we have had a solar eclipse with as great a duration of totality? and how long will it be before we have another as good as this? We shall attempt to provide answers to these two questions and to give some idea of the way in which the problem is handled.

In a paper, "The Maximum Duration of a Total Solar Eclipse" presented before the American Astronomical Society at Ottawa in 1929, Mrs. Isabel M. Lewis (1931) gave an excellent summary of the conditions which must be satisfied if a solar eclipse is to have a maximum duration of totality. She pointed out that it is impossible for all of the conditions to be fulfilled simultaneously, but that the most favourable combination of circumstances for the next few centuries will occur early in the month of July when the sun is at or near apogee, the moon is at perigee and at (near) its ascending node and its latitude is 24′ south, and the observer is on the equator. For such a combination she calculated the greatest possible duration for a total solar eclipse as 7 minutes 31.0 seconds. She did not attempt to select eclipses with totality lasting almost as long as this.

In his paper, "On the Recurrence of Solar Eclipses, with Tables of Eclipses", Simon Newcomb (1879) had laid the groundwork for such a study. In the preparation of his tables of solar eclipses, he developed the concept of "conjunction points". If the ratio of the mean motions of the earth and moon were a rational fraction, then there would be only a finite number of points in either orbit at which conjunction could occur: these points he called conjunction points. Then to take care of the case where the ratio is not a rational fraction, he introduced the idea of moving conjunction points. He pointed out that if the ratio is expanded in a continued fraction, a series of convergents, each a rational fraction, is obtained, with each successive value a better approximation to the precise value of the ratio. However, the values of the mean motions themselves change, and with them, the values of their ratio, the con-

tinued fraction representing it, and the convergents. He took care of all these changes with his moving conjunction points.

In his tables, Newcomb elected to use a set of moving conjunction points which correspond to the saros sequences of eclipses. He assigned the number 1 to the conjunction point at which the solar eclipse of −632 December 12 occurred at the ascending node, and 113 to the one at which the solar eclipse of −603 November 22 occurred at the descending node. It the reader finds the preceding account too complicated, he may elect to think of these numbers of conjunction points simply as numbers assigned to saros sequences of eclipses, each sequence being represented by an eclipse near its middle.

With this brief introduction, we may now turn to Newcomb's own words on the problem of maximum duration:

> . . . The conditions, $g' = 120°$ and $L = 25°$, (g' and L are the mean anomaly and mean longitude of the sun), though not fulfilled at either point, are so near fulfillment that there were then two series of total eclipses nearer the maximum duration than any which occurred for several subsequent centuries. The last of the most favorable series were in the years 663, 681, 699, etc. [Corresponding to conjunction point no. 19.]
>
> To find other series approaching the maximum of totality, we have to pass over more than a thousand years, until the 42nd and 45th conjunction points approach the node. To the 42nd conjunction point belong the series of great eclipses of 1832, 1850, 1868, 1886, etc., of which the maximum was that of 1832 or 1850. The position of the solar perigee is unfavorable at this point; otherwise the duration would have gone on increasing through the next century. But at the 45th conjunction point, the conditions are more nearly fulfilled than they have been for at least twenty centuries, and we shall therefore have a series of eclipses approaching within a very few seconds of the maximum duration of totality. These will occur in the years 2150, 2168, etc.
>
> Passing now to the descending node, we see that in a general way the series occur in the same order. The favorable conjunction points near the present epoch seem to be the 149th, 152nd, 155th, etc. In the first two of these, the sun's mean anomaly is not favorable except when the moon's is unfavorable. The conditions are better fulfilled at the 155th conjunction point, the central eclipse of which takes place in the year 2009. The eclipses of maximum duration will occur two or three periods before the central eclipse, namely, in the years 1955 and 1973. To this series belong the total eclipses of 1865, 1883, etc. The successive eclipses of this series will therefore increase in duration for five or six periods to come, when the duration will probably be greater than that of any that have preceded them during the past thousand years.

To answer the two questions propounded in the first paragraph, we have examined the four saros-sequences mentioned by Newcomb, corresponding to his conjunction points number 19, 42, 155 and 45. In the

case of eclipses before 1851 A.D., we have used the elements given in Oppolzer's "Canon der Finsternisse" (1887), with corrected values of u, to compute the duration of totality for the point on the central line of totality from which the eclipse will be seen at local apparent noon. For eclipses after 1972 A.D., we have used elements determined from the tables in Schoch's "Syzygientafeln" (1928). For the three eclipses in 1886, 1937 and 1955 we have used the values of the duration given in the annual volumes of the *American Ephemeris and Nautical Almanac*. Because there is some interest in knowing the maximum duration of totality in the saros-sequence that provided great durations, we have attempted to determine the eclipse of greatest duration of totality in each of the three sequences besides the current one.

TABLE I

TOTAL SOLAR ECLIPSES OF LONG DURATION OF TOTALITY

Conj. Pt. No.	Date	Duration	Conj. Pt. No.	Date	Duration
19	681 May 23	7m 12s	155*	1937 June 8	7m 04s
"	699 June 3	7 16	"*	1955 June 20	7 08
"	717 June 13	7 15	"*	1973 June 30	7 06
"	735 June 25	7 01	45	2132 June 13	6 57
42	1832 July 27	6 44	"	2150 June 25	7 13
"	1850 Aug. 7	6 52	"	2168 July 5	7 24
"	1868 Aug. 18	6 54	"	2186 July 16	7 29
"	1886 Aug. 29	6 34	"	2204 July 26	7 23

Eclipses marked * occur at the descending node.

In Table I are given our estimates of duration of totality which are probably within 3 per cent. of the truth. This estimate of accuracy is based on a comparison of durations for recent eclipses calculated by our methods with the values given in national ephemerides. There seems to be good reason to believe that the eclipses of maximum duration have been properly selected by our procedures.

Thus we see that the eclipse of June 20, 1955 has the longest duration of totality of any since June 13, 717 A.D. and a longer duration than any until June 25, 2150. Hence it may be said to be the best in an interval of 1433 years and 12 days, that is, for 1238 years in the past and 195 years in the future.

It is seen that the solar eclipse of 2186 July 16 will have a duration of

totality of 7 m. 29s. which is very near the maximum possible. Unfortunately this great duration of totality will occur at a point 45°47′ W., 7°19′ N., in the middle of the Atlantic Ocean. Perhaps by then it will be possible to have a stable platform above the earth's atmosphere, travelling at approximately the speed of the moon's shadow. With jet planes, we have already reached a point where the duration of totality can be greatly extended by travelling in the direction in which the shadow moves.

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THE λ10500 ABSORPTION IN THE SPECTRA OF LATE M-TYPE STARS*

By Andrew McKellar

Abstract

Infra-red spectrograms of R Leonis, M8e and R Cassiopeiae, M7e, obtained with a dispersion of about 150 A./mm. show that the absorption at λ10500 is actually a sequence of bands. Six band heads have been measured at λλ10459, 10484, 10510, 10530, 10547 and 10566. The individual bands are degraded toward longer wave-lengths; they do not appear to correspond to any yet produced in the laboratory.

A wide absorption band centred at about 10600 angstrom units was detected in the spectra of Mira Ceti, M6e, and R Leonis, M8e, by Kuiper, Wilson and Cashman (1947) when they observed certain stellar spectra with an infra-red spectrometer using a lead sulphite cell as detector. Their tracings, made with low resolving power (about 80 A.), revealed the band only as a wide, fairly symmetrical depression. More recently F. D. Miller (1953), using photographic plates with IZ(2) emulsion and the objective prisms on the Curtis Schmidt-type telescope at Ann Arbor, has photographed the same band in the spectrum of R Aurigae, M7e. Again the dispersion was very low (1300 A./mm. at λ10000) and the band was shown as a deep absorption, centred about λ10660, and estimated to be 300 A. wide.

As far as the admittedly scanty evidence to date allows a conclusion to be drawn, the band occurs only among spectra of very late M-type stars. It was not found by Miller (1953) in the spectrum of Z Ursae Majoris, M6e. It was not present on Sandford's (1947) or Herzberg's (1947) spectrograms of α Orionis, M2 and α Scorpii, M1, nor on the plates taken recently at Victoria of α Orionis, M2 and ρ Persei, M3 (McKellar, 1954).

The recent work at Ann Arbor on the λ10600 absorption was being carried on by James Milligan who had available, in addition to the objective-prism plates referred to above, a few spectrograms (dispersion about 500 A./mm.) obtained by F. D. Miller at the Perkins Observatory. Since Milligan was unable to make much headway in the study of the band with the material at his disposal, he suggested that we try to obtain spectrograms with the rather better dispersion (133 A./mm. at λ10000;

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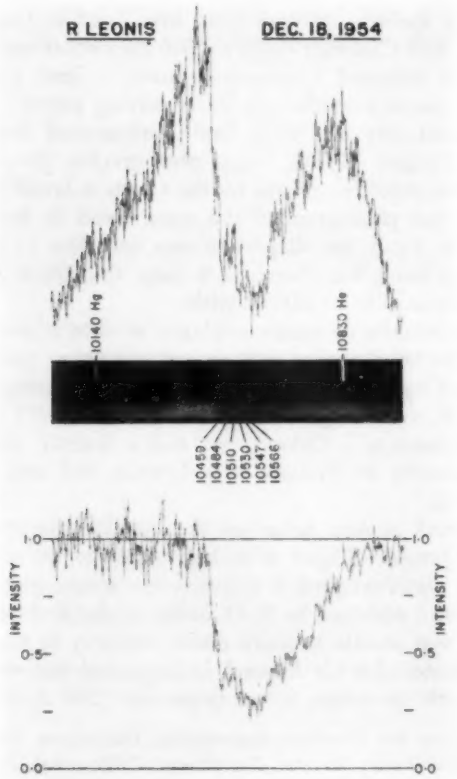
163 A./mm. at λ11000) of the Victoria three-prism spectrograph. On December 18, 1954, spectrograms were obtained of R Cassiopeiae, M7e, and R Leonis, M8e. On that date the former star (period 431 days) was about 53 days after maximum (Kukarkin and Parenago, 1953); the latter star (period 313 days) was about 53 days before maximum (Merrill, 1952).

On the spectrogram of R Cassiopeiae the absorption was moderately strong, the residual central intensity being 65 per cent. On the plate of R Leonis the absorption was quite strong and wide, the residual central intensity being only about 25 per cent., and the width over 300 angstroms. The most interesting feature is the structure in the absorption, which



shows it to be not a band but almost certainly a sequence of at least six bands, degraded toward longer wave-lengths. The accompanying figure shows, in the centre, a reproduction of the spectrum of R Leonis, with a direct intensity tracing above and a rectified intensity tracing (the continuum made horizontal) below. The wave-lengths of the six component band heads were measured as λλ10459, 10484, 10510, 10530, 10547 and 10566. They should be accurate to about ± 2 A.

The bands do not appear to correspond to any yet produced in the laboratory. In general appearance, the sequence is typical of those of many diatomic molecules. Since late M-type spectra are characterized by very strong bands of TiO, one would guess that the λ10460 sequence probably arises from a diatomic oxide. We do know several oxides that are *not* responsible for the bands. With the assistance of Mr. E. H. Richardson, spectrograms of LaO and TiO were obtained but the bands cannot be identified with these oxides. CaO gives bands in the λ10500 region but they do not correspond either in wave-length or in direction of shading to those in the stellar spectra. Infra-red bands of FeO were described by A. M. Bass and W. S. Benedict (1952) but they do not bear any detailed resemblance to the stellar bands; therefore the very tentative suggestion of identity put forward by the Ann Arbor investigators (Miller, 1953) must be abandoned. The identification of the stellar sequence of bands must probably await further laboratory work.

References

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Dominion Astrophysical Observatory,
Victoria, B.C.,
January 1955.

REPORT OF THE NATIONAL SECRETARY

Many items of interest will be noted in the annual reports of the twelve centres of the Royal Astronomical Society established in the principal cities across Canada. A careful reading of these will indicate that the aims and purposes of the Society have been well maintained in the year just closed.

In latter years a number of the centres have been fortunate in acquiring observatories of their own, enabling them to increase their programmes of observations. Montreal as usual heads the list in recorded and accurate work. Edmonton in the last two years shows much interest and activity amongst their members in observations. Each meeting night seems to be enlivened by reports of work done by each of the groups specializing on sun-spots, aurorae, meteors, etc.

It is a pleasure to record that a new centre has been formed in the city of Halifax. For years it has been a matter of regret in the Council that the Society has never been represented in any city in the Maritime provinces, so that the event is doubly welcome.

This interested group was known as the Nova Scotia Astronomical Society and had been in existence for three years. Dr. Beals, when President, visited them on a trip to Halifax, and Dr. Heard, through correspondence with their Honorary President, M. W. Burke Gaffney, consummated the transaction. They start with 30 members.

We are also in correspondence with Prof. J. E. Kennedy, of Fredericton, New Brunswick, which we hope may materialize in another group of enthusiasts being added as a Centre.

The announcement of a total eclipse of the sun visible in Ontario and Northern Canada raised the hopes of a number of our members who made great preparations, but alas! what a disappointment! Only the "exalted" few who rose above the clouds in a plane saw it.

No Honorary Members were proposed for election this year. Four were elected last year, and our President waived the privilege in favour of the succeeding President.

The Council is grateful for the generous response to the appeal for donations to save increasing the cost of ordinary membership. The appeal is being repeated for 1955. Our Treasurer's report will give the details of your added support in 1954.

One of our much esteemed past Presidents, R. Meldrum Stewart, for many years Dominion Astronomer and a member of the Ottawa Centre, passed on during the year on September 2nd.

The thanks of the Society is hereby expressed to the Editors of our

publications. The sale of the OBSERVER'S HANDBOOK is increasing steadily, and 5500 copies have been printed for 1955. The burden of the production with its worrisome details falls on Miss Northcott who has done an excellent job.

Dr. Chant's many friends over the United States and Canada will be interested to know that, although suffering from arthritis in his ninetieth year, he is still taking a lively interest in the affairs of the Society.

Dr. W. R. Hossack, our librarian, has left to take a position with the Defence Research Board at Ottawa. He did a splendid job for the Society in cataloguing our books and separating and evaluating a great backlog of magazines and papers. We wish him much success in his new field. Dr. J. B. Oke, a graduate of the University of Toronto and Princeton University, has been nominated by the Council as successor to Dr. Hossack.

Our membership list for 1955 shows a total of 2091.

E. J. A. KENNEDY, *National Secretary.*

REPORT OF THE LIBRARIAN

The library of the Royal Astronomical Society of Canada has been fortunate indeed this year in regard to donations received for the purchase of books. Mr. Carl Reinhardt of Cobalt, Ontario, gave a very generous donation of $50.00. Dr. Jean McDonald of Victoria, British Columbia, gave a kind donation of $10.00. In addition, Mr. W. R. Sherrick and Mr. Bert Topham of the Toronto Centre have given several books.

During the year, approximately $100.00 was spent for the badly needed binding of periodicals. The back numbers of several outdated periodicals, having little to do with astronomy, have been sold for the sum of $82.00.

Library circulation has approximately doubled over 1953. It is hoped that centres of the Society outside Toronto will in the future make greater use of the "loan by mail" service available to them.

Mrs. Dorothy C. Williamson, the Society's Executive Assistant, has contributed greatly to the successful operation of the library.

In retiring from office, your librarian feels that the library will be in capable hands next year with Dr. J. B. Oke as librarian.

WILLIAM R. HOSSACK, *Librarian.*

REPORTS OF SECRETARIES OF CENTRES

Ottawa Centre

Two meetings of the council were held during the year to arrange for the public meetings and to transact the business of the centre.

Five public lecture meetings were held in the National Museum Lecture Hall.

February 9—G. D. Garland: "Tides in the Solid Earth".
March 16—"Meteorites and Craters". D. K. Norris: "Debris of the Solar System"; J. M. Harrison: "Glaciation and the Ungava Crater".
April 22—J. F. Heard: "The Solar Eclipse of June 30th, 1954, in Northern Canada."
November 16—G. A. Brealey: "Meteor Observing in North-Western Canada".
December 2—Annual dinner meeting. W. S. McClenahan: "Re-Opening of the Pulkovo Observatory, Leningrad, U.S.R.R."

The membership of the centre at the close of the year stands at 94 members.

Ian Halliday, *Secretary.*

Hamilton Centre

During the year 1954, eight regular meetings were held at McMaster University, one joint meeting at London, three field nights and two council meetings to discuss the business of the Centre.

January 7—W. H. Parker, M.A., B.Sc.: "Our Changing Climate".
February 4—W. J. Sled, B.A.,: "Is Man Alone in Space?"; J. H. Sled, Phm.B.: "The Origin of the Earth's Atmosphere".
March 4—Zb. L. Sujkowski, Ph.D.: "The Geology of the Moon".
April 1—A. E. Johns, Ph.D.: "The Solar Eclipse of June 30th, 1954"; C. C. McMullen, M.Sc., Ph.D.: "Radiations from Nuclei."
May 6—T. M. Norton: "Precession of the Equinoxes"; Richard H. Tomlinson, Ph.D.: "Determination of the Age of the Universe and the Earth."
July 7—Telescope Night.
October 6, 7—Field Nights.
November 4—W. S. Mallory, M.A.: "Gravity."
November 27—Trip to London for a joint meeting with the London Centre.
December 2—L. O. Jones: "The History of Our Calendar"; A. E. Johns, Ph.D.: "Stars: Variety in Uniformity."

It is with a feeling of deep regret that the Hamilton Centre announces the death of a faithful member, Mr. M. S. Groh of Preston, Ontario.

The total membership is 89 and includes three life members.

George Murchie, *Secretary-Treasurer.*

Winnipeg Centre

The highlights of the year were:

January 13—B. W. Currie, Ph.D.: "Radio Astronomy".
February 17—G. M. Wiseman: "The Total Lunar Eclipse of January 18"; Miss Arlyne P. Rosenblat: "Night Sky for the Month of February"; B. G. Whitmore, Ph.D.: "Review of *Birth and Death of the Sun* by George Gamow".
March 17—R. G. LaFleche: "The Elements of the Solar System"; R. J. Lockhart: "Interplanetary Space Travel."
April 9—D. R. P. Coats: "Observing a Total Solar Eclipse from the Air"; R. J. Lockhart: "The World Calendar."
May 14—Peter M. Millman, Ph.D.: "Domes against the Sky".
October 13—Films: "A is for Atom"; "Canada's Atom Goes to Work"; Miss Arlyne P. Rosenblat: "Sky for the Month of October."
December 16—Annual Meeting.

G. Marcy Wiseman, *Secretary-Treasurer.*

Victoria Centre

During the year 1954 the Victoria Centre held seven regular meetings:

January 13—A. B. Underhill: "The Development of the Reflecting Telescope."
February 10—A. G. Hill: "Applications of Radar."
March 10—A. McKellar: "Probing the Atmospheres of the Giant Stars."
April 7—H. Bondi: "Modern Trends in Cosmology."
October 13—J. K. McDonald: "Ferut—Canada's Electronic Computing Machine."
November 10—J. A. L. Muir, N. Hutchings: "Amateur Telescope Making."
December 8—Annual Dinner: Palomar Observatory Film.

The 1954 membership stands at 92 including 6 life members and 5 junior members.

In 1954 the Centre offered its twenty-third annual summer course "Summer Evenings with the Stars", to an enrolment of 107 persons. The five meetings included lectures followed by observational periods.

August 2—N. G. Rogers: "Introduction to Astronomy—Stellar Constellations."
August 9—Mrs. J. R. Noble: "The Solar System."
August 16—E. R. Gibson: "The Moon."
August 23—A. H. Joy: "Families of Stars."
August 30—Visit to the Dominion Astrophysical Observatory.

Dorothy M. Edmonds, *Secretary-Treasurer.*

Montreal Centre

The year has been a very active and satisfactory one as will be indicated by the reports of the other officers. The chief event of the year was the securing and development of an observatory for the Centre. This is at least a partial culmination of a long term vision for the Centre to have a home of its own.

The weather has been very poor for observing activities and the year's two big events (the Annual Star Night and the Eclipse Expedition) were ruined by clouds.

Thirteen regular meetings were held during the season with an average attendance of 74. These meetings included a popular introductory series of six given by our own members. Others who spoke before the centre were Messrs. E. R. Patterson, F. DeKinder, Dr. D. E. Douglas and Dr. A. Vibert Douglas of Queen's University, all of whom are members of the Centre. Other meetings were addressed by D. W. R. East and J. Bordan of the McGill Stormy Weather Group and the National President of the Society, Dr. J. F. Heard. At the final meeting the usual lighter nature was maintained by a production of the operetta "The Story of Frederick".

We wish to thank all those who helped the Centre's activities through the year especially those who have made donations to the Observatory Fund, the officers and members who have worked so hard in organising and carrying out the many activities and the City of Westmount as well as the press in helping with Star Night and other activities.

As this is my final report I cannot refrain from expressing my gratitude for the co-operative spirit and friendship which one finds in this Centre.

Henry F. Hall, *Secretary.*

London Centre

During 1954 the London Centre held seven regular monthly meetings and one special observation night in May. The November meeting was held jointly with the Hamilton Centre at London. All meetings were held in the Hume Cronyn Memorial Observatory of the University of Western Ontario. Observations through the observatory's ten-inch refractor were made preceding the meetings when weather permitted.

In June a group of ten, led by W. Gordon Graham, travelled north to Mattice, Ontario, to observe the total eclipse of the sun, but unfortunately the sky was overcast.

Two meetings of the executive committee were held during the year. The membership roll shows 29 paid-up members. The list of meetings is as follows:

February 23—W. G. Graham: "Finding Celestial Objects by means of Right Ascension and Declination"; H. R. Kingston: "Handbook Study."
March 23—E. E. O'Connor: "The Portable Solar System"; W. G. Graham: "How Big is Pluto?"
April 30—W. G. Graham: "Are Flying Saucers Real?"; W. H. Admason: "Handbook Study."
May 21—Observation Night.
June 15—R. J. Lockhart (of the Winnipeg Centre): "A Pictorial Excursion out of this World"; G. R. Magee: "The Total Solar Eclipse of June 30th"; H. R. Kingston: "Handbook Study."
October 21—H. R. Kingston: "Riding the Sky with the Moon"; G. R. Magee: "Handbook Study."
November 27—Joint meeting with Hamilton Centre held at London. R. J. Nicholls: "The Berkeley Conference for Astronomy Teachers"; Refreshments.
December 17—Annual Meeting: W. G. Graham: "The London Solar Eclipse Expedition"; H. R. Kingston: "Handbook Study."

W. Gordon Graham, *Secretary.*

Vancouver Centre

There were seven regular meetings of the Vancouver Centre in 1954, all in the Physics Building of the University of British Columbia. The attendance varied between 57 and 22, with an average of about 35. The speakers were:

January 12—G. L. Pickard, Ph.D.: "Tidal Waves."
February 9—A. R. McCauley, M.A.: "Weather and the Jet-Stream."
March 9—F. A. Kaempffer, Ph.D.: "What is Light?"
April 13—Members' Night; H. G. Reddish: "Cosmical Electricity"; Capt. C. A. McDonald: "Right Ascension."
October 12—A. W. Mackenzie: "Angular Momentum."
November 9—Jean K. McDonald, Ph.D.; "Ferut, Canada's Electronic Computing Machine."
December 14—G. M. Shrum, Ph.D.; "Peace-time Uses of Atomic Energy."

From June to September on such Tuesday evenings as were clear, members of the Centre put out telescopes on the University Grounds. This year, for the first time the Centre had telescopes at the Pacific National Exhibition.

The Annual Dinner was at the Faculty Club on December 14. Twenty-seven members and guests attended. The Annual General Meeting for

the election of officers was held before the regular monthly meeting on that day.

Seven new members joined during the year and the same number withdrew. There are now 41 on the roll.

The Centre is indebted to Dr. Shrum and to the University for the use of the Physics Building.

R. J. CLARK, *Secretary.*

EDMONTON CENTRE

The regular meetings of the Edmonton Centre were held in the Arts and Science Building of the University of Alberta, through the kindness of the authorities. The average attendance was 26 members and visitors. Refreshments after the meetings were much appreciated. The Annual Dinner meeting was held in the banquet room of the Corona Hotel.

HANDBOOK talks were given by Dr. Campbell, news and observing reports were given by Franklin Loehde and Earl Milton, and this information will in future be available in "Star Dust", sponsored by the observers' group.

The main papers were as follows:

December 3—L. E. Gads: "Astronomical Visits."
January 14—E. Phibbs: "Astronomical Distances."
February 11—K. B. Newbound: "Spectroscopy in Astronomy."
March 11—W. C. Wonders: "Maps in Geography."
April 8—D. R. Crosby: "Solar Eclipses and Longitude."
May 13—H. W. Wilson: "The Solar Eclipse of June 30, 1954."
October 14—E. S. Keeping: "Cosmic Dust."
November 18—L. V. Smith: "Our Milky Way."

E. H. GOWAN, *Secretary.*

CENTRE DE QUÉBEC

L'année 1954 a été marquée d'un événement particulièrement important au Centre de Québec: l'organisation d'une expédition d'éclipse. L'Expédition Fleur-de-Lys, mise sur pied à l'occasion de l'éclipse du 30 juin, a commencé à nous occuper et à nous préoccuper dès le mois de janvier. L'envoi de neuf hommes dans les solitudes de l'Ungava, à 600 milles de Québec, avec l'équipment technique permettant l'enregistrement simultané du signal horaire et des divers contacts de l'éclipse, a fait surgir de multiples problèmes dont la solution a pu être trouvée, grâce à un heureux concours de circonstances et au dévouement de nos membres.

Le coût de l'expédition avait été estimé à 3000 dollars, mais la société

s'en est tirée à peu de frais, soit quelques centaines de dollars. Parmi les corps publics dont la collaboration a été la plus appréciée, il faut mentionner la Compagnie Hollinger, qui exploite le minerai de l'Ungava, l'Université Laval, et divers Ministères du Gouvernement de la Province de Québec. La société n'oublie pas non plus ce mécène anonyme qui a versé 500 dollars au fonds de l'expédition et qui lui a ainsi permis de ne pas entamer ses réserves.

Du côté technique, nous avons bénéficié des conseils pertinents du Dr Heard, Directeur de l'Observatoire David Dunlap, et du Dr Smiley, Directeur de l'Observatoire Ladd.

L'expédition n'a pas observé l'éclipse, comme on sait. Une dépression venant du nord-ouest était rendue au-dessus de l'île Uranie, le matin du 30, et il pleuvait légèrement dès la fin de la nuit crépusculaire. A soixante-dix milles au sud-est, à Knob Lake, le ciel est demeuré parfaitement clair tout le long de l'éclipse.

La seconde partie de l'année 1954 a été occupée surtout à la rédaction d'un Supplément à Notre Univers Merveilleux, un travail qui demandait d'être très soigné, puisque le Supplément doit servir de manuel de classe dans les collèges.

En raison de ses travaux supplémentaires, la société n'a pas tenu de séances générales mensuelles, sauf celle de ce soir dont le programme consistera dans la présentation des films de l'Expédition Fleur-de-Lys, que nous verrons pour la première fois, la plupart d'entre nous.

Malgré une saison d'été déplorable, l'activité est demeurée à peu près la même à l'Observatoire. On a cependant noté que les constructeurs de télescopes se faisaient plus nombreux que d'habitude et que les instruments réalisés étaient de meilleure qualité.

L'année 1954 marquait aussi le 10e anniversaire du Graphique du Ciel. Les abonnés à cette publication ont profité de l'occasion pour féliciter en grand nombre l'Académie des Sciences du Maryland de cette contribution à la cause de l'astronomie populaire et, comme résultat, le Graphique du Ciel paraîtra pour une 11e année consécutive.

PAUL-H. NADEAU, *Le secrétaire.*

WINDSOR CENTRE

Seven regular meetings and two executive meetings were held during the year. The average attendance was 37. The meetings were as follows:

January—B. Donn, Ph.D.: "Interstellar Matter and Evolution of Stars and Galaxies"; Chas. A. Bell: "Current Events".

February–Keith Pierce, Ph.D: "Moon"; W. L. Swanson: "Current Events."
March–William Lillers, Ph.D.: "Meteors as Probes of the Upper Atmosphere"; W. G. Mitchell: "Current Events".
April–Alfred E. Johns, Ph. D.: "Plumbing the Depths of Outer Space"; Cameron Montrose: "Current Events".
June–Held at the home of Mr. and Mrs. D. Bawtenheimer. Films.
October–Wm. Mitchell: "Construction of Lenses and Mirrors for Telescopes"; D. Bawtenheimer: "Current Events."
November–Annual Meeting.

P. C. HAWKES, *Secretary.*

CENTRE FRANÇAIS DE MONTRÉAL

Le Centre français de Montréal a tenu neuf réunions générales au cours de la saison 1954. Le conseil s'est réuni deux fois à son siège officiel, à la bibliothèque de l'Ecole Polytechnique.

Voici la liste des séances régulières et des sujets traités:

21 janvier–Jean Asselin, Ing.P.: "Une Etoile."
4 février–J. P. Laviolette: "La Navigation." Présentation de la Médaille Chant à Jean Naubert.
4 mars–Pierre Guillemette: "L'Atome source d'énergie solaire".
1 avril–Frère Robert, f.e.c.: "Sondages de l'Univers."
29 avril–Adolphe Martin, Ing.P.: "L'Ether existe-t-il?"
27 mai–Jean Asselin, Ing.P.: "L'Eclipse totale du Soleil du 30 juin 1954."
1 octobre–Reprise des activités; Films sur l'astronomie; Visite de l'usine de filtraiton de la Ville de Montréal.
11 novembre–Adélard Rousseau: "La construction d'un télescope portatif." Visite des serres du jardin botanique.
2 décembre–Madame Eugène Pelletier; "La femme canadienne–française et l'astronomie."

F. LAFOREST, *secrétaire.*

FINANCIAL STATEMENT, 1954

1. NATIONAL TREASURER

INCOME		DISBURSEMENTS	
Grant: Government of Canada	$ 3,000.00	Printing of publications	$ 7,537.95
Grant: Province of Ontario	500.00	Grants to Centres	1,212.50
Fees from Centres	4,037.15	Office salaries	2,100.00
Fees from general members	1,003.96	Rent	720.00
Donations etc.	1,728.82	Stationery and supplies	487.40
Subscriptions to JOURNAL	414.89	Office expenses, postage, etc.	217.55
Sale of HANDBOOKS	1,057.10	Library books and bindings	127.58
Sale of pub. and reprints	2,015.07	Bank charges and exchange	86.56
Advertising revenue	340.00	General expenses	50.24
Interest from Life Memb. Fund	60.31		
Totals	$14,157.30		$12,539.78

Excess of income over expenditures	$ 1,617.52
Deficit—December 31, 1953	752.11
Net surplus—December 31, 1954	$ 865.41

BALANCE SHEET

ASSETS		LIABILITIES	
Current Assets		*Current Liabilities*	
Cash on hand and in bank	$ 3,371.14	Outstanding cheques	$ 250.23
Remittances due from Centres	1,008.00	Accounts payable	3,286.94
Accounts receivable—publications and advertising	870.77		$ 3,537.17
Prepaid rent	60.00	*Deferred Income*	
	$ 5,309.91	Membership fees received for 1955	$ 436.63
Special Funds		Prepaid subscriptions and advertising	470.70
Invested in bonds—Shown at cost (Market value $10,812.15)	$10,840.00		$ 907.33
On deposit in bank	1,629.17	EQUITIES	
	$12,469.17	*Current Account Surplus*	$ 865.41
		Reserves for Special Funds	
		Life Membership Fund	$ 2,387.66
		Building Fund	8,182.31
		Southam Press Fund	1,899.20
			$12,469.17
	$17,779.08		$17,779.08

J. H. HORNING, *National Treasurer.*
M. ALTMAN, *Auditor.*

II. REPORTS OF TREASURERS OF CENTRES

OTTAWA CENTRE

Receipts		Disbursements	
Balance from 1953	$109.39	Fees to National Council	$234.00
Grant from National Council	95.00	Printing, postage and stationery	47.25
Members' fees	234.00	Rent	20.00
Donations	55.50	Advertising	30.04
Donation to Ottawa Centre	10.00	Donations to National Council	55.50
Sale of Handbooks	26.50	Cost of Handbooks	22.50
Bank interest	1.21	Bank charges	.61
Proceeds of Annual Dinner	196.00	Costs of Annual Dinner	154.00
Miscellaneous	1.00	Balance carried forward	164.70
Totals	$728.60		$728.60

S. A. Mott, *Treasurer.*

HAMILTON CENTRE

Receipts		Disbursements	
Balance from 1953	$138.27	Fees to National Treasurer	$198.00
Members' fees	207.00	Rent	53.42
Grant from National Council	71.00	Postage and stationery	31.96
Donations	4.00	Printing	25.45
Bank interest	.99	Expenses *re* meetings	116.34
Field Night	93.46	Exchange	.10
		Balance carried forward	89.45
Totals	$514.72		$514.72

George Murchie, *Treasurer.*

WINNIPEG CENTRE

Receipts		Disbursements	
Balance from 1953	$221.47	Fees to National Treasurer	$231.00
Members' fees	156.00	Miscellaneous	99.00
Junior members	4.00	Balance carried forward	113.97
Miscellaneous	8.50		
Grant from National Treasurer	54.00		
Totals	$443.97		$443.97

G. Marcy Wiseman, *Secretary-Treasurer.*

VICTORIA CENTRE

Receipts		Disbursements	
Balance from 1953	$225.88	Fees to National Treasurer	$253.00
Members' fees	258.00	Rent	12.00
Grant from National Council	40.00	Postage and stationery	25.17
Bank interest	1.55	Printing	14.44
Summer course profit	12.13	Expenses *re* meetings	35.03
Miscellaneous	.10	Exchange on cheques	3.04
		Library, books, etc.	35.35
		Insurance	10.00
		Repair of building	50.00
		Express	4.12
		Miscellaneous	11.30
		Balance carried forward	84.21
Totals	$537.66		$537.66

Number of Junior Members included in this report: 4.

Dorothy M. Edmonds, *Secretary-Treasurer.*

MONTREAL CENTRE

Receipts		Disbursements	
Balance from 1953	$479.94	Fees to National Treasurer	$741.00
Members' fees	741.00	Postage and stationery	161.64
Donations	208.92	Rent	86.00
Grant from National Council	264.00	Expenses *re* meetings	18.00
Bank interest	6.67	Library	46.62
Fee for Centre Francais	3.00	Equipment	19.93
Donations for National Treasurer	12.00	Dues—Film Council	5.00
		Insurance	7.35
		Advertising	37.10
		Expenses *re* Star Night	26.17
		Exchange on cheques	1.98
		Fee remitted to Centre Francais	3.00
		Donations to National Treasurer	12.00
		Miscellaneous	3.59
		Balance carried forward	546.15
Totals	$1,715.53		$1,715.53

OBSERVATORY FUND

RECEIPTS		DISBURSEMENTS	
Balance from 1953	$444.51	Alterations to building	$1,408.10
Donations	2,680.28	Postage	11.50
Interest on bonds	3.00	Balance carried forward	
Bank interest	5.33	Dom. of Canada Bonds	100.00
		Cash in bank	1,613.52
Totals	$3,133.12		$3,133.12

C. N. S. YARNELL, *Treasurer.*

LONDON CENTRE

RECEIPTS		DISBURSEMENTS	
Balance from 1953	$ 2.16	Fees to National Treasurer	$ 81.00
Members' fees 1954	81.00	Subscriptions, *Sky & Telescope*	10.00
Grant from National Council	31.00	Postage	1.15
Interest	.07	Expenses *re* meetings	21.42
Donations	11.00	Exchange on cheques	.65
		Donations to National Treasurer	10.00
		Balance carried forward	1.01
Totals	$125.23		$125.23

W. GORDON GRAHAM, *Treasurer.*

VANCOUVER CENTRE

RECEIPTS		DISBURSEMENTS	
Balance from 1953	$ 49.26	Fees to National Treasurer	$100.50
Members' fees	100.65	Donations to National Treasurer	64.00
Grant from National Council	53.00	Expenses *re* meetings	10.75
Bank interest	.60	Postage	7.50
Donations	64.00	Exchange on cheques	.41
		Balance carried forward	84.35
Totals	$267.51		$267.51

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Balance from 1953	$173.36	Fees to National Treasurer	$165.00
Members' fees	114.00	Postage and stationery	3.50
Associates' fees	2.00	Subscriptions, *Sky & Telescope*	8.89
Grant from National Council	51.00	Expenses *re* meetings	10.50
Interest	4.38	Exchange on cheques	.15
		Balance carried forward	156.70
Totals	$344.74		$344.74

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Balance from 1953	$417.29	Fees to National Treasurer	$219.00
Members' fees	219.45	Observatory	44.02
Grant from National Council	60.00	Donation to R.A.S.C.	2.00
Donations	503.00	Expédition Fleur-de-Lys	1102.05
Refund (Expedition)	273.00	Administration	84.85
Miscellaneous	2.35	Balance carried forward	27.31
Bank interest	4.14		
Totals	$1479.23		$1479.23

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Receipts		Disbursements	
Balance from 1953	$ 87.37	Fees to National Treasurer	$128.00
Members' fees	122.00	Postage and stationery	21.60
Grant from National Council	43.00	Printing	8.53
Donations	26.00	Expense *re* meetings	38.00
Bank interest	1.60	Miscellaneous	8.95
		Subscription, *Sky & Telescope*	5.00
		Balance carried forward	71.89
Totals	$279.97		$279.97

Number of Junior Members included in this Report: 1.

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Receipts		Disbursements	
Balance from 1953	$103.89	Fees to National Treasurer	171.00
Members' fees	174.00	Rent	18.00
Grant from National Council	53.00	Postage and stationery	17.56
Donations	56.00	Expense *re* meetings	12.50
Interest in bank	.61	Miscellaneous	20.50
		Subscription, *R.A.S.*	25.00
		Balance carried forward	122.94
Totals	$387.50		$387.50

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NOTES FROM OBSERVATORIES

Dominion Astrophysical Observatory, Victoria, B.C.

The one-tenth scale model of the 72-inch telescope and the dome, constructed before the Observatory was built, has been acquired by the Observatory. It has spent the intervening 40 years in Toronto and Ottawa. The model is presently being overhauled and repaired, and when this work is completed, it will be on exhibition on the main floor of the dome building. It is a working model and will serve to illustrate the motions and operation of the dome and telescope.

Four members of the staff, Jean K. McDonald, Anne B. Underhill, K. O. Wright, and A. McKellar, attended the Conference on Stellar Atmospheres, sponsored by the National Science Foundation of the United States, and held in Bloomington, Indiana, September 29–October 2.

The calendar year 1954 was unusually poor for telescopic observations. The total observing time was 84 per cent. of the 36-year average, there being about 30 fewer clear nights.

Mrs. Dorothy Edmonds resigned as astronomical assistant in September. Mr. W. R. H. White joined the staff in November as an assistant in seismology.

Visitors to the Observatory in recent months have included: Dr. B. N. Moyls (Univ. of B.C.), Dr. A. R. Sandage (Mount Wilson and Palomar), Dr. Beverly Oke (Toronto), Dr. P. van de Kamp (Sproul), Dr. T. S. Jacobsen (Washington), Dr. W. B. Lewis (Chalk River), Dr. R. W. Nicholls (Western Ontario), Dr. H. L. Welsh (Toronto), Mr. C. H. Schauer (Research Corporation, New York) and Dr. D. C. Rose (National Research Council). Dr. Rose travelled on H.M.C.S. *Labrador* by the North-West Passage from Halifax to Esquimalt, and his mode of arrival at the Observatory was by helicopter.

J. K. McD.

VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

021403 Omicron Ceti. The first variable star for which we have an authentic record of discovery is Mira. In August 1596 Fabricius observed a third magnitude star which was not in the star catalogues. The star disappeared from view within a few months, but years later was again observed by Bayer and Holwarda. In 1660 it was recognized to have a periodicity of about eleven months.

Mira is one of the best observed of all the bright variables and many light curves have been published, but it is of interest to study a continuous curve covering many epochs. The accompanying light curve was prepared at the request of Dr. Leo Goldberg for use in the revision of his book, "Atoms, Stars and Nebulae," one of the series of Harvard Books on astronomy. The plotted points are 10-day mean values of A.A.V.S.O. observations, and include observations by the variable star groups of New Zealand and Japan, when they were available. Thirty-six epochs are shown in the curve, from 1922 to the end of 1954, and they illustrate the well-known variation in brightness of both maxima and minima of Mira. There is no apparent regularity or alternation of high and low maxima, such as is found in some of the long-period variables.

Much of the irregularity in depths of minima of Mira is probably due to its close visual companion. A recent paper by Dr. A. H. Joy, "Spectroscopic Observations of Mira Ceti, 1934–1952," *The Astrophysical Journal Supplement Series,* vol. I, no. 2, 1954, sums up the state of our knowledge of this interesting object. Remarkably little is actually known about the companion. Its existence was first suspected by Dr. Joy in 1923, from a strange sidewise displacement of spectral lines of Mira at minimum. R. G. Aitken examined the region with the 36-inch refractor at Lick Observatory and was amazed to see a companion about ¾ magnitude fainter than Mira and about 1″ south following it. He said it would be an easy object for a 12-inch telescope. Later observations by double-star observers show no certain change in distance or position angle of the two components, but from a consideration of the distance and masses involved, P. P. Parenago (*Variable Stars,* vol. 7, p. 199, 1950) has computed a probable orbit with a period of 14 years.

The companion cannot be seen unless Mira is near minimum light. Observations are further limited by the closeness of the pair, but it is difficult to understand why it was not seen by earlier double-star observers. Variation in the light of the companion has been confirmed by several observers, and most of them have suspected sudden changes. Estimates of the relative intensity of the spectrum of Mira and its companion indicate a period around 14 years, with the minima corresponding approximately to the times of periastron of Parenago's elements. This is a difficult coincidence to explain.

All of these peculiarities lead to one point—more observations of the companion of Mira are needed. Every visual observer with a telescope of 12-inches or larger

should make it his duty to look for the companion whenever Mira is fainter than magnitude 7.5. Perhaps some day we can solve the mystery.

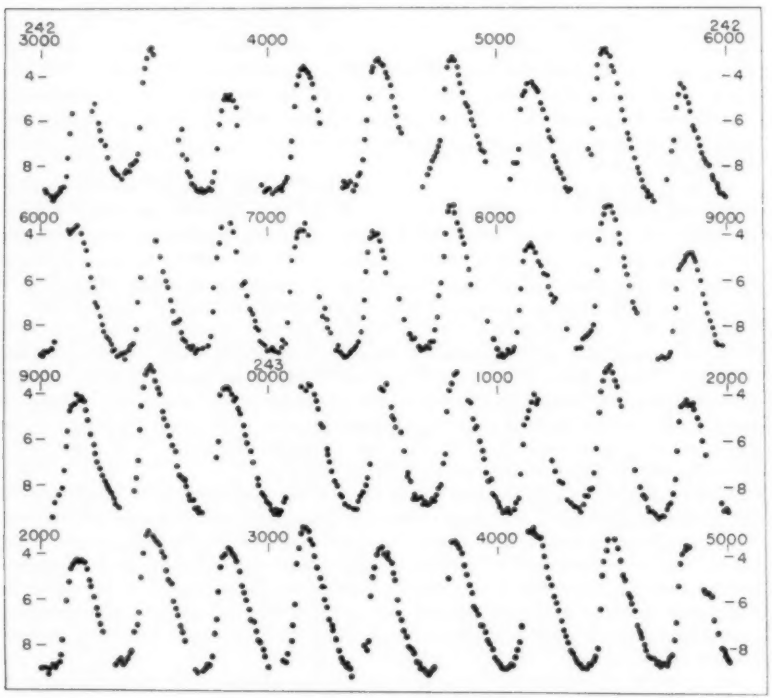
225859 UV Cas. A recent addition to the A.A.V.S.O. programme is the R CrB-type variable, UV Cassiopeiae. Dr. Herbig of the Lick Observatory suggested it to our California observer, Thomas Cragg, and furnished him with a chart showing comparison stars and visual magnitudes. Other observers are now co-operating, and their efforts are paying off. The star was constant at 11th magnitude from July 1954 to early October, when it started to fade. It has now leveled off and for more than a month has been at about 12.1 magnitude.

None of the other R CrB stars on our observing programme show any sign of activity, with the exception of a possible drop in 145971 S Aps, noted by deKock the last of November 1954.

054319 SU Tauri, an R CrB type variable, dropped from 9½ magnitude in the latter part of January to the 13th magnitude in the middle of February.

Notes on the Z Camelopardalis-type variables during 1954.

005840 RX And showed little or no variation between 11.5 and 12th magnitude, until October, when it began to vary erratically from 11 to 13.



Light curve of Mira, 021403 *o* Ceti, from A.A.V.S.O. observations 1922–1954.

020657a TZ Per varied between 12.2 and 15 during January and February, then remained around 13.5 the rest of the observing season. In October, through December, it varied from 12.5 to 14.5.

054705 CN Ori is considered to have a "cycle" length of 19 days, with a range of magnitude from 11.8 to 14.7. There was an observed 12.0 maximum on J.D. 2434800, when the star was brighter than 13 for about 8 days; and another on 4832, when it was brighter than 13 for about 10 days, with no indication of a maximum in between.

081473 Z Cam. Following a period of constant median brightness, Z Cam was active throughout the year, varying from 10.0 to 14.5 with intervals between maxima of 20 to 48 days.

195377 AB Dra is difficult for visual observation as its maxima are seldom brighter than 12.5 and minima are below 15. However, many maxima were observed during the year, at intervals of 8 to 15 days. A 12th magnitude maximum was well observed on J.D. 2434983.

Spring Meeting of the A.A.V.S.O.

At the invitation of Dr. N. E. Wagman, Director, Allegheny Observatory of the University of Pittsburgh, and Mr. Arthur L. Draper, Director, Buhl Planetarium and Institute of Popular Science, the Spring Meeting of the American Association of Variable Star Observers will be held in Pittsburgh on the week-end of May 27–29, 1955. Plans are being made for a feature lecture by Dr. Wagman; sessions for shorter papers; instrument exhibits by J. W. Fecker, Inc., and the Amateur Astronomers Association of Pittsburgh; and a visit to the Allegheny Observatory and other points of interest. It is hoped that members and friends from all points of the compass will gather in Pittsburgh for the Memorial Day week-end.

Nova Search Programme. During the months of November and December 1954, reports were received from the following eight observers. Listed for each observer is the month the observations were received, the areas observed (in italics), the number of nights the region was checked, and finally, the limiting magnitude.

Adams, Robert M., Dec.–*1, 2, 16, 17*: 3, 8.

Diedrich, Delorne, Nov.–*40*: 4, 6; Dec.–*94*: 1, 6.

Diedrich, George, Nov.–*Dome*: 5, 2; *56*: 1, 6; *78*: 6, 6; Dec.–*Dome*: 2, 2; *56*: 2, 6; *78*: 3, 6.

Perry, Wendell, Nov.–*33, 34, 35, 49, 50, 63*: 1, 5.5.

Ragland, Beaufort S., Nov.–*23*: 3, 5; *23*: 2, 5.5; *23*: 3, 6; *23*: 4, 6.5; Dec.–*23*: 1, 5.5.

Rick, Louis, Nov.–*Dome*: 3, 2; *18, 63*: 3, 5; Dec.–*Dome*: 1, 2; *18, 63, 65*: 1, 5.

Rosebrugh, David W., Nov.–*Dome*: 7, 3; *1, 34*: 6, 4; Dec.–*Dome*: 1, 2; *Dome*: 1, 3; *1, 34*: 2, 4.

Sullivan, William H., Nov.–*1, 2, 6–12, 15–22, 30–34, 39–43, 70, 77–79, 89, 90*: 6.0; Dec.–*9, 10, 18, 19, 25, 26, 31–33, 37, 40–43, 46, 47, 53, 54, 62–64, 67, 68, 89, 90–94, 100, 102, 103*: 6.5.

Observations received during November and December 1954: In November 6,447 observations were contributed by 69 observers, and in December 5,233 by 58, a total of 11,680 for the two months.

Observer	Nov.		Dec.		Observer	Nov.		Dec.	
	No. Var.	No. Ests.	No. Var.	No. Ests.		No. Var.	No. Ests.	No. Var.	No. Ests.
Abbey, L. B., Jr.	16	32	7	14	Kimball, M.	11	34	24	30
Adams, R. M.	70	212	78	241	de Kock, R. P.	139	485	131	576
Ancarani, M.	30	91	16	23	Knowles, J. H.	9	30	...	...
Anderer, J. A.	11	13	18	41	Lacchini, G. B.	24	59	23	48
Anderson, C. E.	239	344	40	91	Lee, C. V.	...	...	1	1
Aronowitz, C.	156	371	195	322	Lonak, E.	5	9	3	3
Barber, W. F., Jr.	4	6	...	...	Maran, S. P.	61	164	49	61
Behar, A.	1	8	...	...	McPherson, C.	6	6	21	21
Beidler, H. B.	30	42	40	58	Mebius, W. G.	...	...	7	12
Bicknell, R. H.	11	28	8	21	Miller, W. A.	33	43	1	1
Boutell, H. G.	7	16	8	12	Montague, A. C.	45	58	34	50
Buckstaff, R. N.	13	24	10	17	Morgan, F. P.	...	...	1	5
Bull, H. M., 3rd	25	26*	10	11	Mount, A. W.	8	10	17	34
Calamaras, H.	1	1	...	...	Oravec, E. G.	141	492	129	375
Carpenter, C. B.	31	31	65	68	Overbeek, M. D.	93	735	...	...
Charles, D. F.	31	36	...	...	Owen, T.	10	17	...	...
Cragg, T. A.	217	223	240	249	Parker, P. O.	18	18	...	...
Crouse, L.	8	8	...	...	Paulton, E. M.	4	5	1	1
Culp, C.	1	2	2	2	Pearcy, R. E.	2	2	6	6
Darsenius, G. O.	23	55	23	98	Peltier, L. C.	29	145	20	64
Diedrich, DeL.	2	5	2	2	Perry, W. L.	12	18	...	...
Diedrich, G.	7	13	2	2	Pohl, E.	13	69	...	...
Elias, D. P.	...	...	83	283	Renner, C. J.	...	...	232	281
Erpenstein, O. M.	5	6	7	14	Rizzo, P. V.	33	46	29	45
Fernald, C. F.	229	492	174	221	Rosebrugh, D. W.	19	78	21	72
Ficonetti, R.	18	25	10	15	Royer, R.	20	26	27	57
Ford, C. B.	180	184	21	21	Schultz, G. W.	5	20	10	44
Gaustad, J. E.	17	17	...	...	Segers, C. L.	...	...	27	86
Gleason, W. S.	...	...	5	7	Semos, E. B.	1	6	...	...
Glenn, W. H.	...	...	1	1	Skaritka, P.	181	303	191	428
Goldenblatt, P. P.	...	...	4	4	Taboada, D.	100	110	149	293
Goodsell, J. G.	5	5	...	...	Thomas, M. A.	2	2	4	11
Greenley, R. M.	30	30	...	...	Tutundjian, D.	1	1	...	...
Hales, LaV.	2	3	...	...	Venter, S. C.	97	297	...	...
Hartmann, F.	154	164	164	171	Walsh, J. F.	5	5	1	1
Hein, C.	8	15	8	25	Watson, P. S.	28	32*	10	11
Hein, G.	156	508	163	472	Weitzenhoffer, K.	...	...	5	5
Hinn, A. R.	9	9	...	...	Wyckoff, J.	29	38	19	21
Kastin, H.	11	11	47	84	Zelvin, J.	16	16	...	...
Kelly, F. J.	8	12	...	...					

*Also 28 minutes of observation of AE Aquarii.

Note added in Press:

054319 SU Tauri, an R CrB type variable, dropped from 9½ magnitude in the latter part of January to the 13th magnitude in the middle of February.

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